TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.
1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*
Aug. 2	9.14	11.38	Aug. 1	9.83	8.48	Aug. 3	17.37	13.13	Aug. 4	8.81	8.18
9	8.48	11.81	2	11.38	9.14	11	15.11	16.20	13	7.29	8.81
11	13.61	14.60	7	14.10	13.13	12	15.11	20.57	18	9.14	8.48
14	10.59	16.79	8	9.83	9.83	13	12.24	14.10	26	7.04	6.50
15	16.20	19.23	9	10.21	7.04	14	10.59	18.59	29	8.18	7.87
16	15.11	17.37	13	15.11	14.10	16	9.14	11.38	......	......	......
19	15.65	17.96	14	14.60	14.60	18	9.83	9.83	......	......	......
20	14.60	17.96	16	10.97	12.68	......	......	......	......	......	......
22	15.11	13.61	18	13.13	12.24	......	......	......	......	......	......
23	14.10	20.57	19	11.38	11.81	......	......	......	......	......	......
26	9.52	10.59	21	10.97	8.48	......	......	......	......	......	......
27	9.14	11.81	22	12.24	16.20	......	......	......	......	......	......
......	......	......	23	16.20	16.79	......	......	......	......	......	......
......	......	......	25	9.47	8.18	......	......	......	......	......	......
......	......	......	26	8.48	8.81	......	......	......	......	......	......
......	......	......	27	7.87	7.57	......	......	......	......	......	......
......	......	......	28	7.04	7.87	......	......	......	......	......	......
......	......	......	30	9.14	8.81						
......	......	......	31	8.18	9.14	......	......	......	......	......	......

TABLE 3.—*Daily totals and departures of solar and sky radiation during August, 1919.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departure from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
1	405	679	170	− 73	202	−379	− 73	202	−379
2	616	611	488	139	137	− 59	66	339	−438
3	569	253	700	92	−218	155	158	121	−283
4	333	357	523	−143	−111	− 20	15	10	−303
5	225	351	609	−251	−114	68	−236	−104	−235
6	223	270	593	−251	−193	56	−487	−297	−179
7	462	620	684	− 9	159	152	−496	−138	− 27
8	500	639	584	31	179	56	−465	41	29
9	630	578	611	164	120	87	−301	161	116
10	579	574	518	115	117	− 2	−186	278	114
11	550	216	604	89	−239	89	− 97	39	203
12	458	518	345	0	64	−166	− 97	103	37
13	100	470	669	−355	18	163	−452	121	200
14	442	563	643	− 10	112	141	−462	233	341
15	486	475	480	37	26	− 18	−425	259	323
16	500	575	656	54	128	161	−371	387	484
17	378	384	686	− 64	− 60	195	−435	327	679
18	425	556	661	− 14	115	173	−449	442	852
19	473	540	230	37	102	−255	−412	544	597
20	550	271	567	118	−165	85	−294	379	682
Decade departure							−108	101	568
21	288	597	558	−141	164	80	−435	543	762
22	522	540	545	96	110	70	−339	653	832
23	498	512	539	76	85	67	−263	738	899
24	491	522	508	72	98	40	−191	836	939
25	328	592	405	− 88	171	− 60	−279	1,007	879
26	509	549	168	95	131	−295	−184	1,138	584
27	376	585	251	− 36	170	−209	−229	1,308	375
28	503	564	530	93	153	72	−127	1,461	447
29	478	332	463	70	− 76	7	− 57	1,385	454
30	158	465	612	−248	60	158	−305	1,445	612
31	433	539	620	28	138	168	−277	1,583	780
Decade departure							+ 17	+1,204	+ 98
Excess or deficiency since first of year. gr.-cal.							−4,697	−3,366	−1,938
Excess or deficiency since first of year. per cent							−5.0	−3.6	−1.8

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Director, Astrophysical Observatory.

[Dated: Smithsonian Institution, Washington, September, 1919.]

In continuation of the publications begun in February, 1919, I give herewith the values of the solar constant of radiation obtained at Calama, Chile, for the months of June and July, 1919.

I was present in Calama at the time that many of these observations were made, and in cooperation with the observers there worked out a new method of observing which has been employed for some of the days of observation included in the following tables, and which shall be briefly described as follows:

My colleagues, Mr. Fowle and Mr. Aldrich, as well as those in Calama, and myself have felt very keenly the desirability of devising some method of determining the solar constant of radiation which would be independent of changes in the transparency of the atmosphere during the period of observation. I had hoped that this might be done in some simple form by the aid of the pyranometer, that instrument which we devised several years ago for the purpose of measuring the brightness of the sky. It is well known that when the sky becomes more hazy the direct beam of the sun is reduced in intensity, but the scattered light of the sky is at the same time increased. Accordingly, it would seem that a pyranometer measurement of the brightness of a limited area of the sky near the sun would furnish an index of the state of the transparency of the atmosphere at the moment of observation, and this, combined with the usual observations of the solar intensity at the earth's surface by the pyrheliometer, and combined further with the determination of the quantity of the aqueous vapor between the observer and the sun (which is indicated by the state of the great infra-red absorption bands, ρ and ϕ) might give the means of estimating the solar radiation outside the atmosphere from observations made at a single instant of time.

When I reached Calama, after having observed the total eclipse of the sun at La Paz and having held a conference with Messrs. Wiggin and Clayton of the Argentine Weather Service at La Quiaca, Argentina, I found that Messrs. Moore and Abbot had prepared data giving the pyrheliometry, the transparency of the atmosphere for nearly 40 wave lengths, the function ρ/ρ_{sc}, and pyranometer values representing the intensity of the radiation of the sky in a zone 15° wide surrounding the sun. All these values were tabulated with solar constant values for 60 days of observation. They were taken for each day at the periods when the air masses were 2 and 3, respectively. I spent almost a week in working over these data, trying to find some method of combining them along the lines which I have suggested above, but without success. Mr. Moore, however, had once or twice suggested to me that if we knew the coefficient of atmospheric transmission for all of the individual wave lengths on a given day, and had observed with the spectrobolometer and pyrheliometer at air mass 2 or at air mass 3, we could determine the solar constant from these data at once. I had always replied to him that there are no means of determining the transparency of the atmosphere at these wave lengths without the process of taking successive bolographs during several hours of time, which brought in the very errors which we were endeavoring to avoid. All simple means having failed to give a satisfactory method, Mr. Moore's suggestion recurred to me, and I actually found that it is possible, by noting the value of the function ρ/ρ_{sc}, and the intensity of the sky light in the neighborhood of the sun, to determine at once the transmission coefficients for all wave lengths. This we do by means of plots in which the data for the 60 days mentioned are employed. These data were used in the following manner:

Taking the value obtained at air mass 2 by the pyranometer for the limited area of sky around the sun, dividing it by the value of ρ/ρ_{sc} at the corresponding time, we obtain a function which we may call "F." Plotting values of "F" as abscissæ against values of the transmission coefficients for each measured wave length as ordinates, we obtain about 40 plots. These for the infra-red region of the spectrum are nearly straight lines, but they become more and more convex toward the axes of coordinates for the rays of shorter wave lengths. In the 60 days which were available for the investigations, the function "F"ranged through values running from 100 to more than 1,000 of a certain scale, while the function "a," that is the transmission coefficient, ranged only through a very few per cent. For a large portion of the spectrum, including the infra-red region, the range of "a" was hardly more than 1 or 2 per cent. Accordingly great error is allowable in the function "F" without greatly affecting the accuracy of the inference as to the value of the function "a." In short, by means of the function "F" we are able to determine the function "a" for all wave lengths, with highly satisfactory accuracy, from observations at a single point of time. Thus changes of the atmospheric transparency during the period of observation are avoided.

We shall hereafter employ this new method in combination with the old, not only for air mass 2 but for air mass 3, and shall check one against the other frequently for a considerable period of time until we are abundantly satisfied of the accuracy of the new method of observation. In general we regard observation at air mass 3 as of half the weight of observation at air mass 2. Hitherto, the new method has enabled us to save a number of days of observation which, owing to the obvious changes in transparency of the atmosphere, due to formation or disappearance of clouds, would otherwise have been lost, and some of the observations published herewith for June and July are of this character.

As it is impossible to use our former criterion, based upon the several hours of observation, to determine the excellence of the day, we have altered the statement of the grade by the introduction of two new symbols, "S" meaning satisfactory, and "U" meaning unsatisfactory, for those days in which the solar constant has been determined by the new method. So far as we have as yet been able to compare the results by the old and the new methods, they are on the average closely identical. For instance, on July 1 three values of the solar constant were computed: 1, by the old process; 2, from observations at air mass 2; 3, from observations at air mass 3. The results obtained were as follows: 1.948, 1.940, 1.955, all agreeing within less than 1 per cent, and the mean of the results by the new process agreeing identically with the result by the old.

The new process requires but two or three hours of work where the old required about 15, so that if it continues to appear satisfactory as now a very great gain in labor will result from it. Not only is this so, but a still greater gain, we think, will come in accuracy for we have now eliminated the fruitful source of error depending on the variability of the atmospheric transparency during the observations.

In the future we expect, if all goes well, to determine about two-thirds of the solar constant values exclusively by the new process and the other third at intervals by the old, in addition, to assure ourselves that nothing is going astray. An advantage of the new method is that on days when the early morning is unsuitable for observation but later it clears away so as to be satisfactory for 15° around the sun, a good solar constant value can be obtained by the new method where nothing at all of value could be obtained by the old. It is probable that at Calama the increase in the number of days fit for observation owing to this improvement will be four or five days a month, or possibly more. Also some of the days when we would have had great distrust of the results, owing to probable changes of transparency, will now be made of almost or quite equal excellence to the others.

Apart from this (as it seems to me), very valuable result of my visit to Calama, I was much impressed with the excellent character of the outfit there and with the great zeal and thoroughness with which Messrs. Moore and Abbot are carrying on their observations.

I now give results for June and July. An explanation of the symbols and arrangements of the tables heretofore employed will be found by the reader in the MONTHLY WEATHER REVIEW for February, 1919. Beginning with the month of June, the following slight changes will be made in the publication of the results:

First, a new column, headed "Method," will be inserted after the column headed "Solar Constant." In this will be found the symbols E_0, M_2, M_3, W.M., and occasionally, where the new method has been employed at air masses—differing from 2 and 3, such a symbol as $M_{2.5}$ will be found. The significance of these symbols is as follows: E_0 indicates that the observation was made and reduced by the old method heretofore employed. M_2, M_3, or M, with some other subscript, means that observations were made and reduced by the new method from air mass 2, air mass 3, or some other value which was more suitable on the day in question. The symbol W.M. means that the solar constant value preceding it was the weighted mean of all of the results for the day as determined by the best judgment of the observers at Calama. Thus, on July 21 we have given four values, respectively, 1.947 by the old method, marked "E_0;" 1.955 by the new method from air mass 3, marked "M_3"; 1.955 by the new method at air mass 2, marked "M_2"; and 1.953 marked "W.M.," which is the weighted mean according to the best judgment of the observers at Calama. The values marked "W.M." are to be preferred in the use of the data for purposes of comparison with the phenomena of the weather.

In the next column, marked "Grade," we have introduced, as above indicated, the new symbols "S" and "U," with the suffixes "plus" or "minus" to indicate the degree of satisfactoriness or unsatisfactoriness which prevailed in determining the solar constant by the new method.

The columns marked "Humidity" are to be interpreted as follows: Where the observation has been made by the old method, as indicated by the symbol E_0, the values of humidity are to be understood as the *mean* of all those determined during the interval of the observations. Those which occur, as for example on June 25, on the days when the solar constant was not determined by the old method at all are to be taken as obtained at the time corresponding to the air mass given as a subscript under the letter M in the column headed "Method." Thus, on June 25 the values of humidity correspond to air mass 2; that is to say, to the time when the sun was at 60° zenith distance.

In other respects there is no change in the character of the tables.

Date.	Solar constant cal.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity.			Remarks.
					ρ/ρ_{so}	V. P.	Rel. hum.	
A.M.						Cm.	P. ct.	
June 1	1.962	E_0	VG	0.882	0.645	0.08	11	Cloudless except distant cirri in southwest.
P.M.								
June 2	1.898	E_0	E−	.877	.558	.24	18	
3	1.933	E_0	E−	.874	.707	.18	10	Cirri in west at start drifting to north.
A.M.								
June 4	1.989	E_0	E−	.866	.738	.06	7	
5	1.947	E_0	E	.867	.740	.07	10	
9	1.955	E_0	E−	.877	.498	.21	26	Distant cirri disappearing early.
10	2.013	E_0	VG−	.839	.531	.22	27	
14	1.972	E_0	E−	.859	.372	.44	43	Many cumuli scattered about sky.
15	1.873	E_0	VG+	.872	.432	.33	42	Many scattered cumuli passing over sun at intervals.
	1.918	M_2						
	1.903	W.M.						
16	1.927	E_0	E−	.875	.436	.31	36	Cumuli in distant northeast.
P.M.								
19	1.934	E_0	E−	.869	.543	.27	24	Scattered small cumuli in east.
A.M.								
20	1.956	E_0	VG+	.874	.700	.11	18	Cirri near sun at start.
21	2.013	E_0	E−	.856	.686	.08	10	Cirri in distan west.
22	1.959	E_0	E−	.871	.652	.08	10	
23	1.975	E_0	E−	.871	.756	.06	9	Sky cloudless. Smoke toward west.
24	1.952	E_0	E−	.876	.723	.04	5	Few cirri in southwest disappearing by 10:00.
25	1.955	M_2	S	.874	.735	.04	6	Small cirri scattered about sky.
26	1.926	M_2	S	.878	.767	.15	15	Thin cirri in northeast.
27	1.964	E_0	S	.861	.782	.10	15	Thin cirri in northeast mostly below sun.
	1.938	M_2						
	1.938	W.M.						
P.M.								
28	1.972	M_2	S	.873	.723	.12	8	Many cirri in east and rather uneven in west.
A.M.								
29	1.969	M_2	S	.864	.610	.30	31	Thin cirri and streakiness in east. Small cumuli forming over Andes.
30	1.962	M_2	S	.861	.662	.31	29	Sky cloudless but hazy and very dusty.
A.M.								
July 1	1.948	E_0	VG+	.859	.638	.14	16	
	1.925	M_3						
	1.934	M_2						
	1.935	W.M.						

Date.	Solar constant cal.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity.			Remarks.
					ρ/ρ_{so}	V. P.	Rel. hum.	
A.M.						Cm.	P. ct.	
July 2	1.918	M_2	S−	.867	.664	.13	12	
3	1.928	F_0	VG+	.860	.600	.14	17	
	1.927	M_3						
	1.917	M_2						
	1.922	W.M.						
4	1.968	M_3	S	.865	.479	.16	21	Low cumuli in east.
6	1.964	M_3	S	.869	.521	.19	20	Cirro-cumuli in east, cirri in west.
9	1.947	M_2	S	.872	.636	.32	45	Scattered cirri in north and east, and some cumuli over Andes.
10	1.951	M_2	S	.869	.635	.09	11	Some cirri in distant northeast.
11	1.945	M_3	S+	.869	.528	.10	13	Distant cirri in east and west.
	1.946	M_2						
	1.946	W.M.						
12	1.932	F_0	E−	.869	.487	.13	18	Considerable cirri in south and distant west; also below sun.
	1.969	M_3						
	1.947	M_2						
	1.949	W.M.						
13	1.929	M_3	S	.877	.564	.13	16	Scattered cirri around west, south, and east.
	1.937	M_2						
	1.934	W.M.						
14	1.953	M_3	S	.870	.556	.10	14	Scattered cirri, especially in south and west.
15	1.949	M_3	S	.850	.641	.09	11	Considerable cirri in southwest and some in north and east.
	1.954	M_2						
	1.952	W.M.						
17	1.952	F_0	G	.853	.686	.09	13	Low cirri in southwest.
	1.933	$M_{2.5}$						
	1.964	M_2						
	1.955	W.M.						
18	1.951	F_0	VG+	.873	.552	.07	8	Some low cirri in east—small patches in southwest.
	1.986	M_3						
	1.963	M_2						
	1.966	W.M.						
19	1.984	M_2	S	.866	.488	.17	15	Small cirri scattered about sky.
	1.976	M_3						
	1.979	W.M.						
20	1.955	M_3	S	.864	.538	.22	21	
	1.951	M_2						
	1.952	W.M.						
21	1.947	F_0	E	.857	.573	.17	23	
	1.955	M_3						
	1.955	M_2						
	1.953	W.M.						
22	1.983	M_3	S−	.858	.472	.21	28	
	1.952	M_2						
	1.960	W.M.						
23	1.961	M_3	S+	.873	.617	.13	17	
	1.962	$M_{2.5}$						
	1.957	M_2						
	1.959	W.M.						
24	1.928	F_0	VG+	.875	.636	.10	13	
	1.962	M_2						
	1.951	W.M.						
25	1.957	M_3	S+	.873	.729	.09	10	
	1.961	M_2						
	1.960	W.M.						
26	1.868	M_3	[illegible]	.865	.743	.06	7	
	1.935	M_2	S					
	1.918	W.M.						
27	1.891	M_3	S−	.866	.667	.08	8	
	1.929	M_2						
	1.916	W.M.						
28	1.959	F_0	E	.863	.562	.08	9	
	1.959	M_3						
	1.947	M_2						
	1.955	W.M.						
29	1.951	$M_{1.58}$	S−	.869	.588	.20	12	Scattered cirro-cumulus, especially in east.
30	1.939	M_3	S	.868	.496	.17	20	
	1.922	M_2						
	1.928	W.M.						
31	1.892	M_3	S−	.872	.591	.14	18	
	1.938	M_2						
	1.915	W.M.						